Airborne Internet

Transformational Aircraft Communication Using a Broadband Mesh Network

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7th ICNS
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What you're going to hear

R&D to make aircraft nodes on the SWIM network

Methodology is to create a mesh network using the aircraft themselves to carry the signals.

We've conducted flight demonstrations extending the SWIM network to aircraft. We moved live weather, 20Mb files, aircraft position data, and conducted simultaneous VTCs

We've validated the air ground link performance

We're moving ahead with system simulation

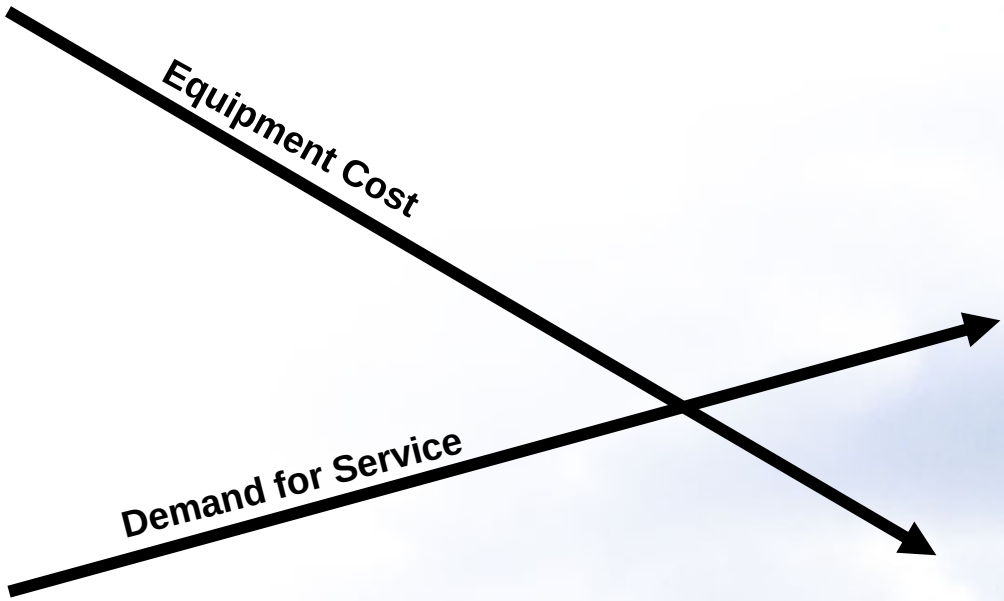
Objective

To Enable A Safer, More Secure, More Cost Efficient GAS
By Eliminating Communications As A Constraint
On The Economic Viability Of Aviation Related Applications

- VERY LOW COST
- VERY HIGH SPEED
- SCALEABLE
- UBIQUITOUS
- SECURE
- OPEN
- EVOLUTIONARY

WE WANT TO HAVE THE SAME EFFECT ON AVIATION COMMUNICATIONS THAT THE TRANSITION FROM COPPER WIRE TO FIBEROPTIC CABLE HAD ON TERRESTRIAL COMMUNICATIONS

Why Now?



Airlines: “If it increases costs we don’t want it”

Internet to Aircraft

Aircell
Airshow
Air TV
AeroSat
ARINC
AT&T Wireless
Boeing Connexion
Honeywell
ICO Global
In Flight Network
Inflightonline Inc.
INMARSAT
LiveTV
NewsCorp
Rockwell Collins
Teledesic
Tenzing
Thompson

Technical feasibility is not the issue

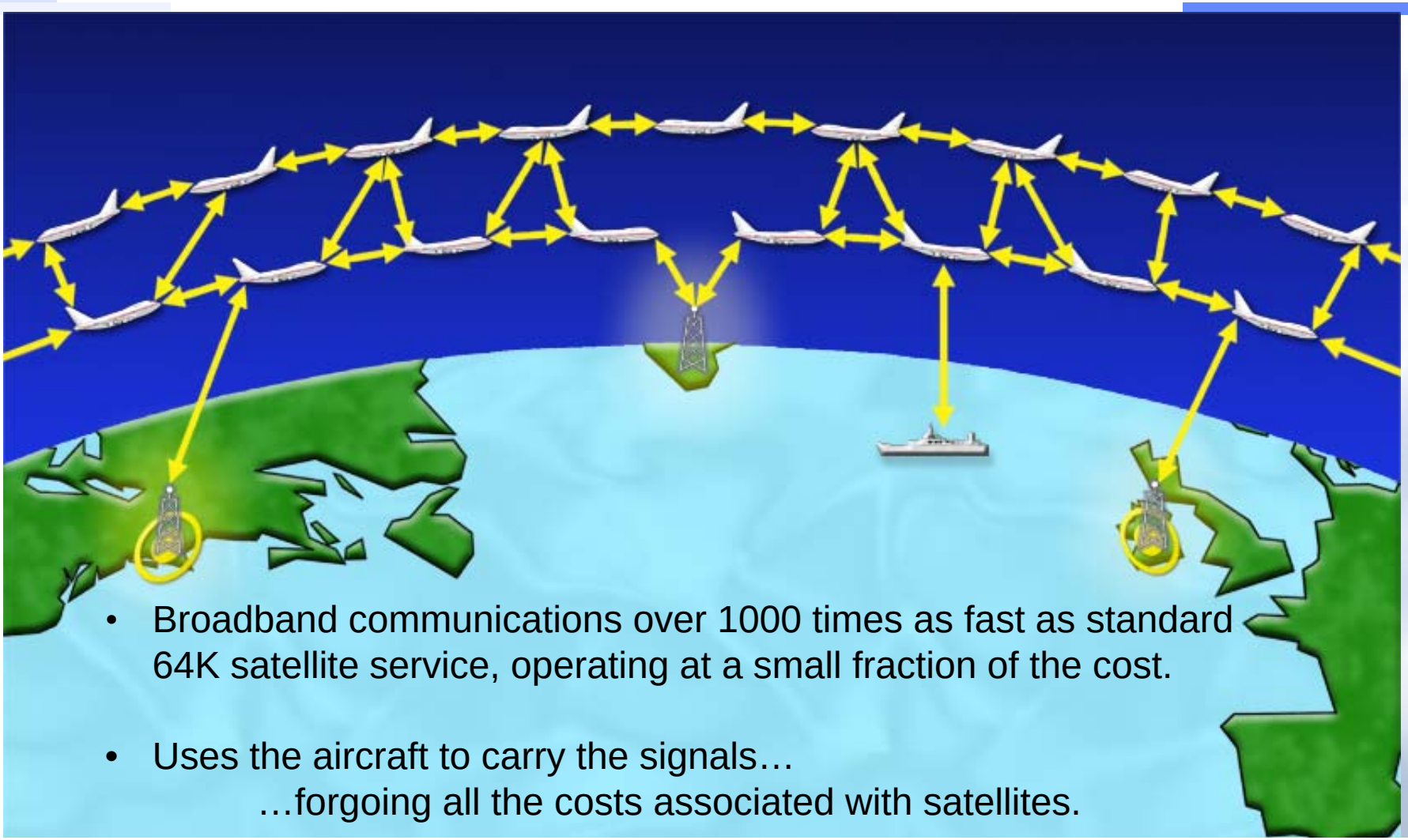
Data can be moved to aircraft

- **At high speed**
- **With ubiquitous coverage**
- **At low cost**

But not all three in a single solution

Airborne Internet Requires a System of Systems

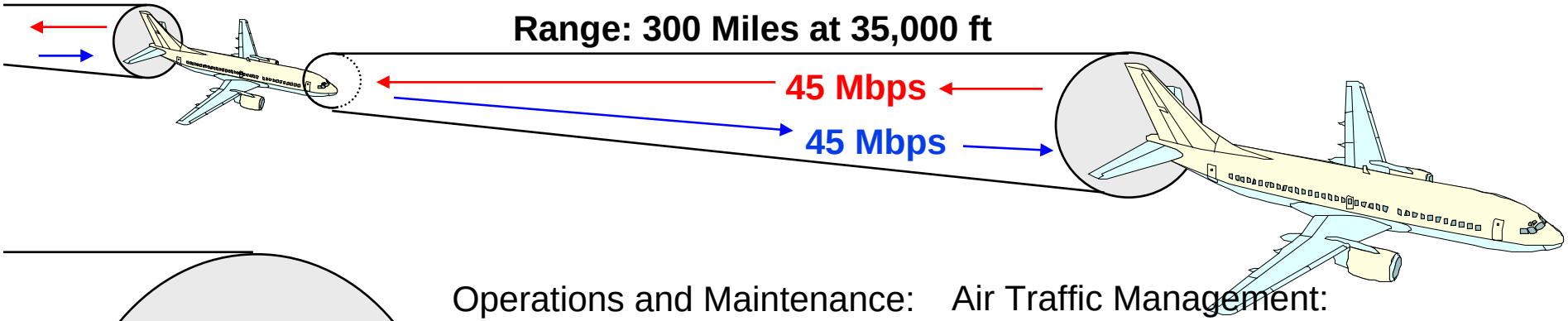
Lowering the Average Cost
Increasing the Average Speed



- Broadband communications over 1000 times as fast as standard 64K satellite service, operating at a small fraction of the cost.

- Uses the aircraft to carry the signals…
  …forgoing all the costs associated with satellites.

Capabilities and Applications…



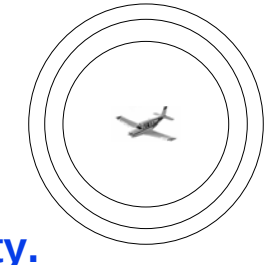
Applications

Operations and Maintenance:
- Engine Monitoring
- Crew Communications
- Fault Reporting
- Diversion Management

Cabin Services:
- Internet Access
- Programming Distribution

Air Traffic Management:
- System Capacity
- Hazardous Weather Avoidance
- Collaborative Decision Making
- Conformance Monitoring

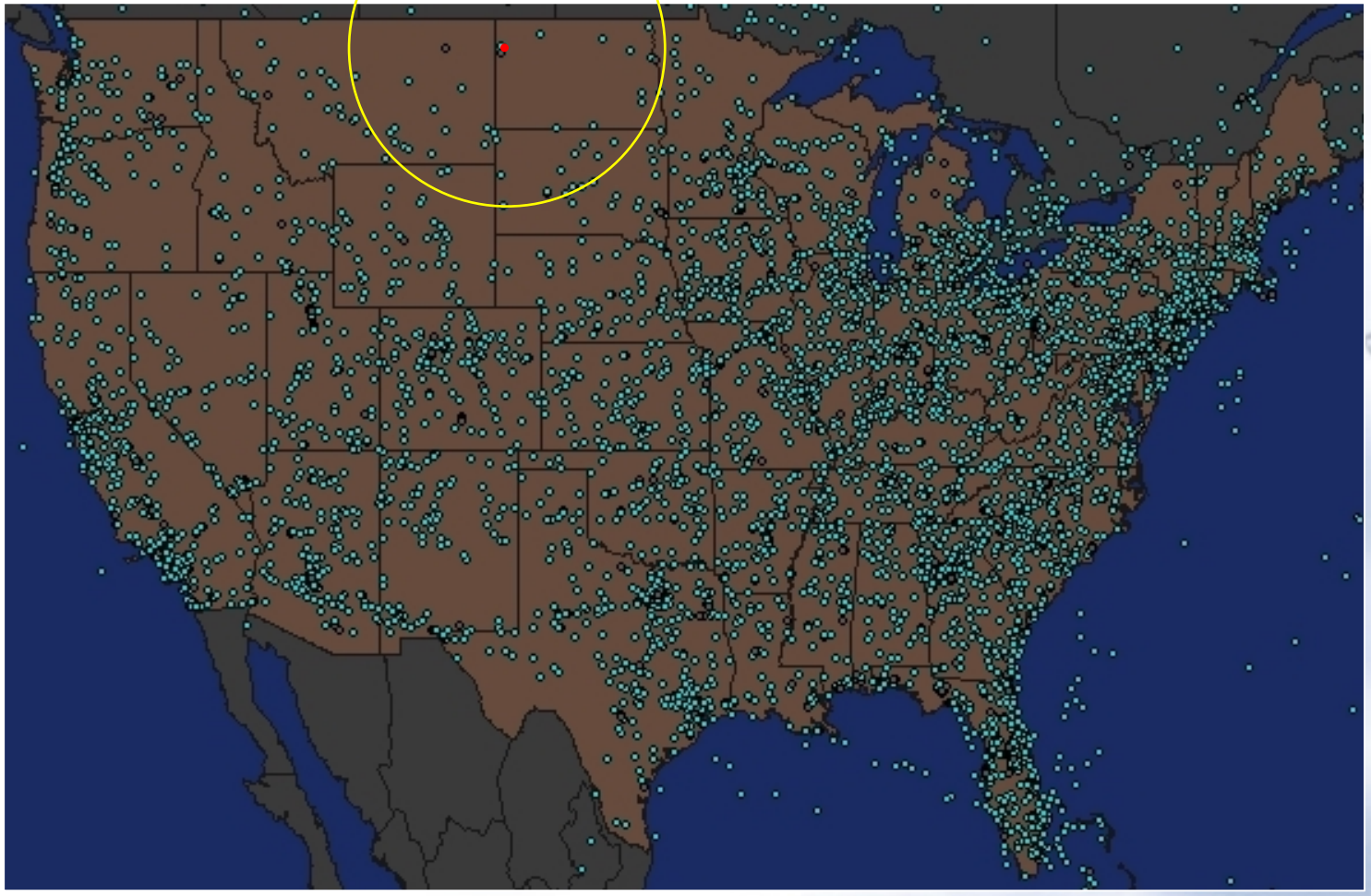
Safety & Security:
- Transportation Security
- Real Time Black Box Transmission
- Telemedicine



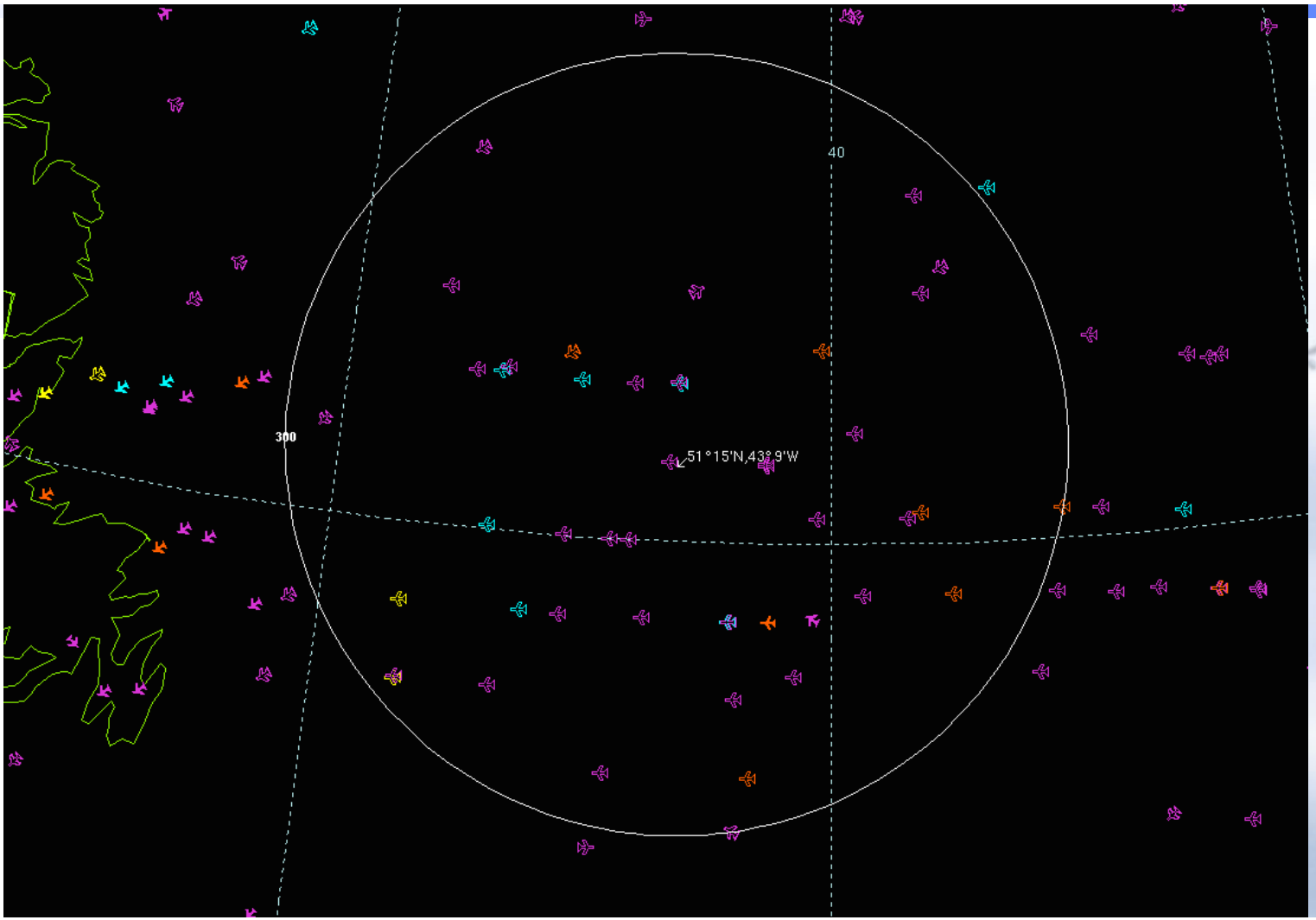
Decision making requires real-time information…

…real-time information requires connectivity.

Network Formation over the U.S.



North Atlantic Traffic Density



Air to Ground Latency

AeroSat AI Latency/node:

1ms RF

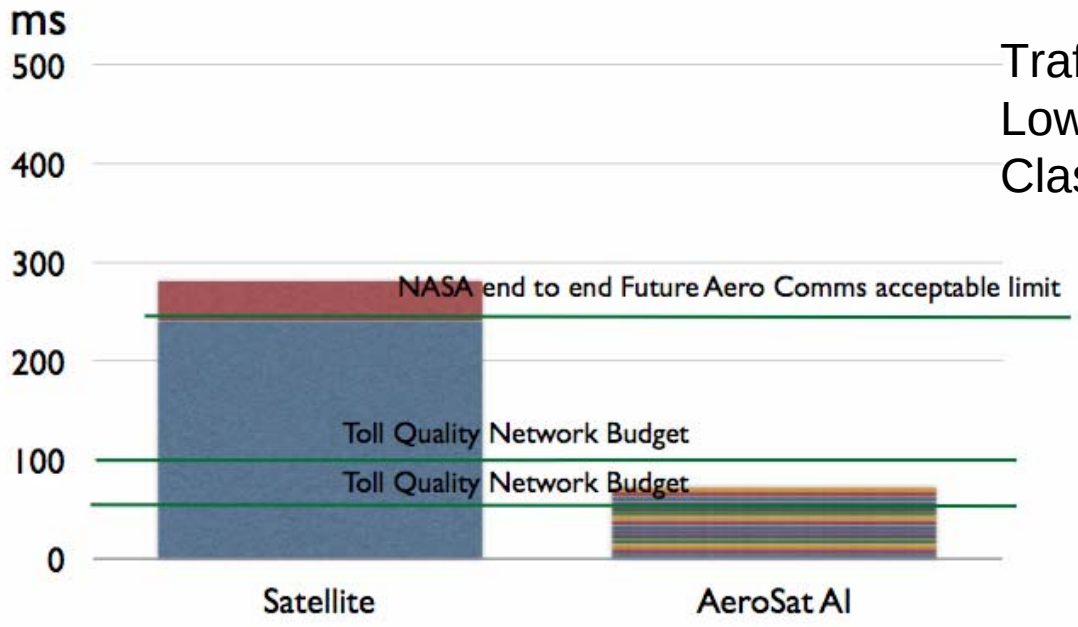
4ms Router

5ms Total/node

Traffic Prioritization:

Low Latency Queueing

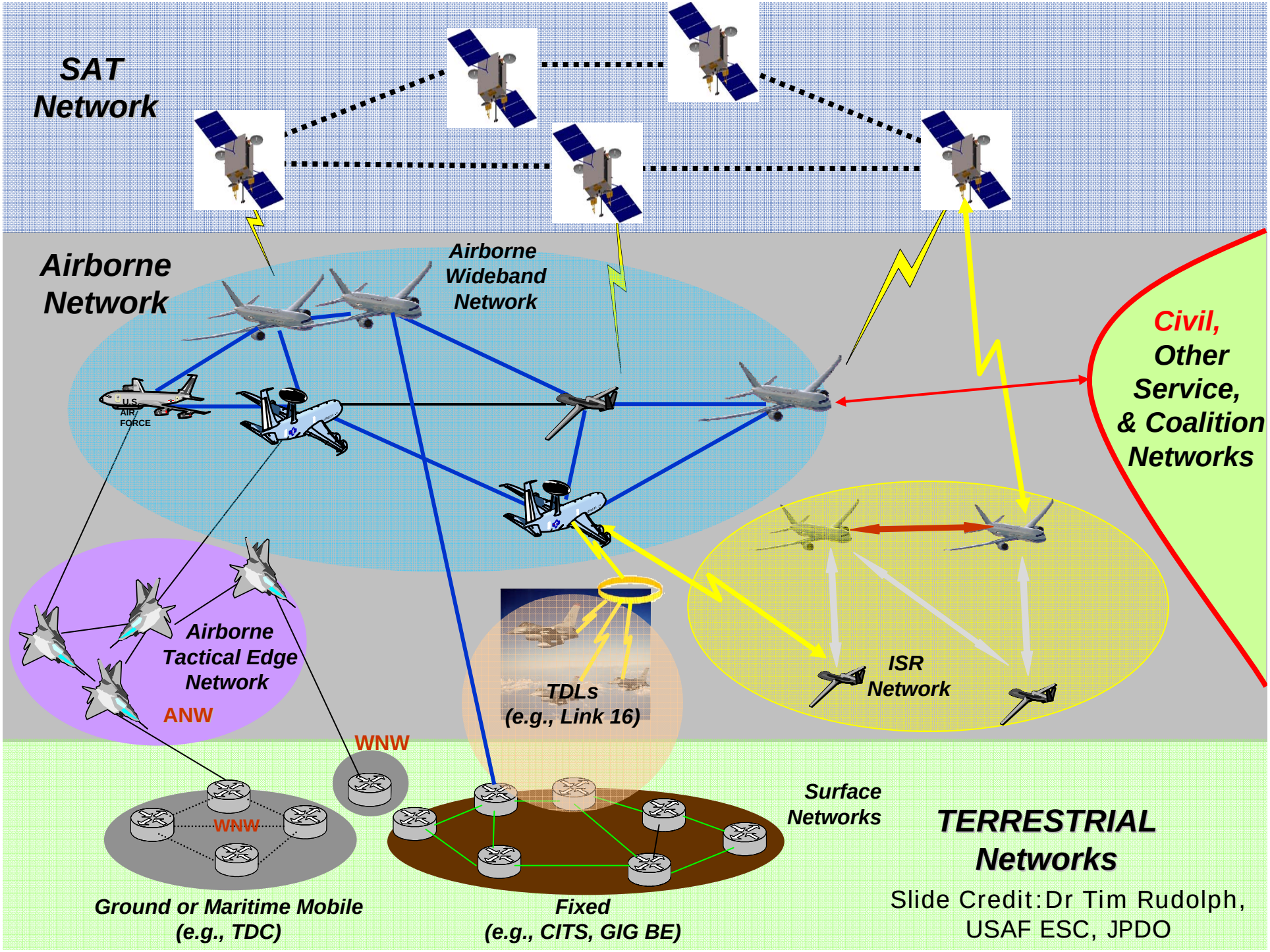
Class-Based Weighted Fair Queueing

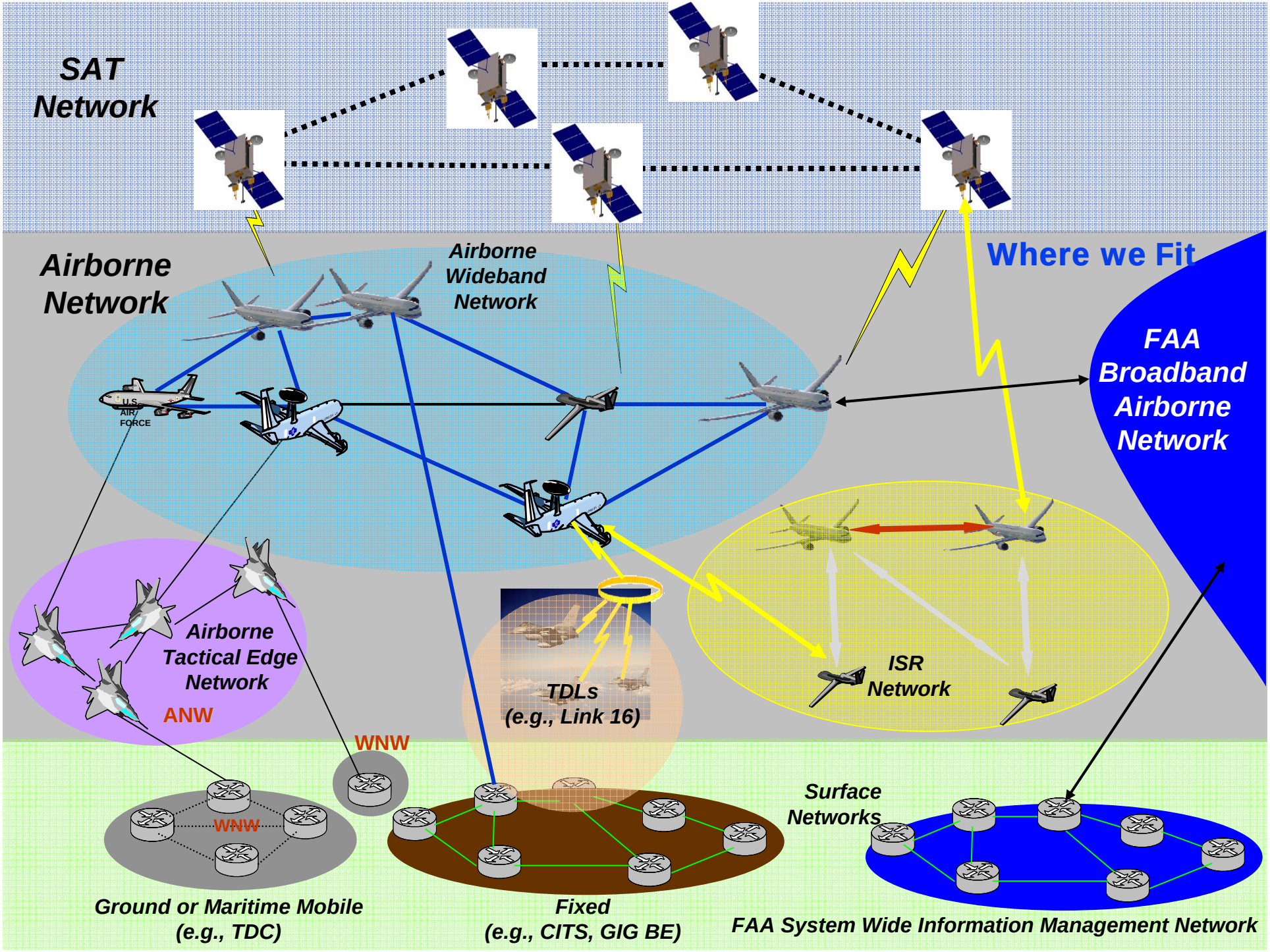


Assumes 15 hops - 4350 miles aircraft to ground

Network Deployment

Incremental
Begin with a single base node
Add airborne connections
Network expands geographically
Add a second base node
Add airborne connections
Network further expands


SAT Network
Airborne Network
Airborne Wideband Network
U.S. AIR FORCE
Civil, Other Service, & Coalition Networks
Airborne Tactical Edge Network
ANW
TDLs (e.g., Link 16)
ISR Network
WNW
WNW
Surface Networks
TERRESTRIAL Networks
Ground or Maritime Mobile (e.g., TDC)
Fixed (e.g., CITS, GIG BE)
Slide Credit: Dr Tim Rudolph, USAF ESC, JPDO


SAT Network
Airborne Network
Airborne Wideband Network
Where we Fit
FAA Broadband Airborne Network
U.S. AIR FORCE
Airborne Tactical Edge Network
ANW
TDLs (e.g., Link 16)
ISR Network
WNW
WNW
Surface Networks
Ground or Maritime Mobile (e.g., TDC)
Fixed (e.g., CITS, GIG BE)
FAA System Wide Information Management Network

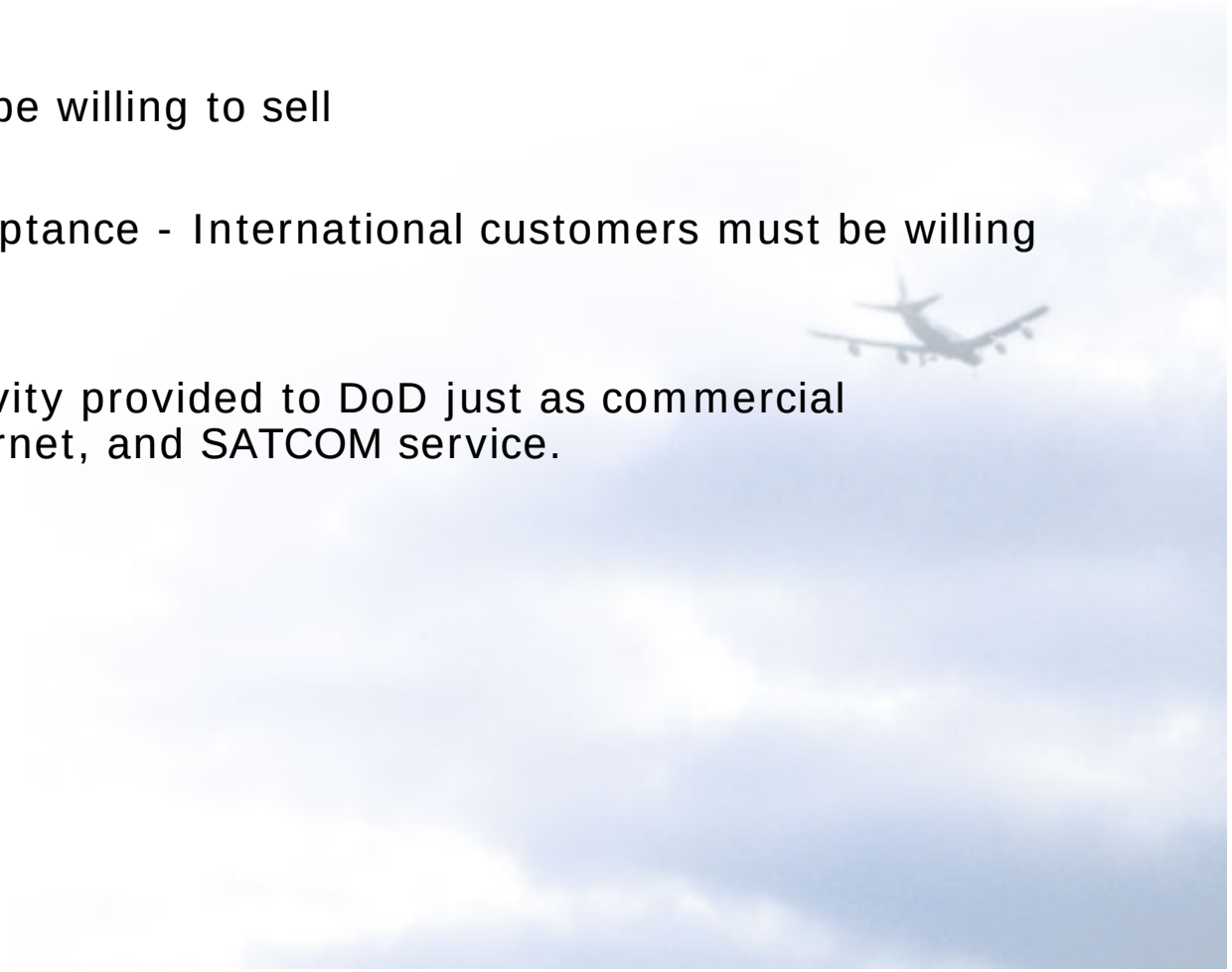
Civil v. Military requirement

Cost - less than $200K / aircraft

ITAR - U.S. must be willing to sell

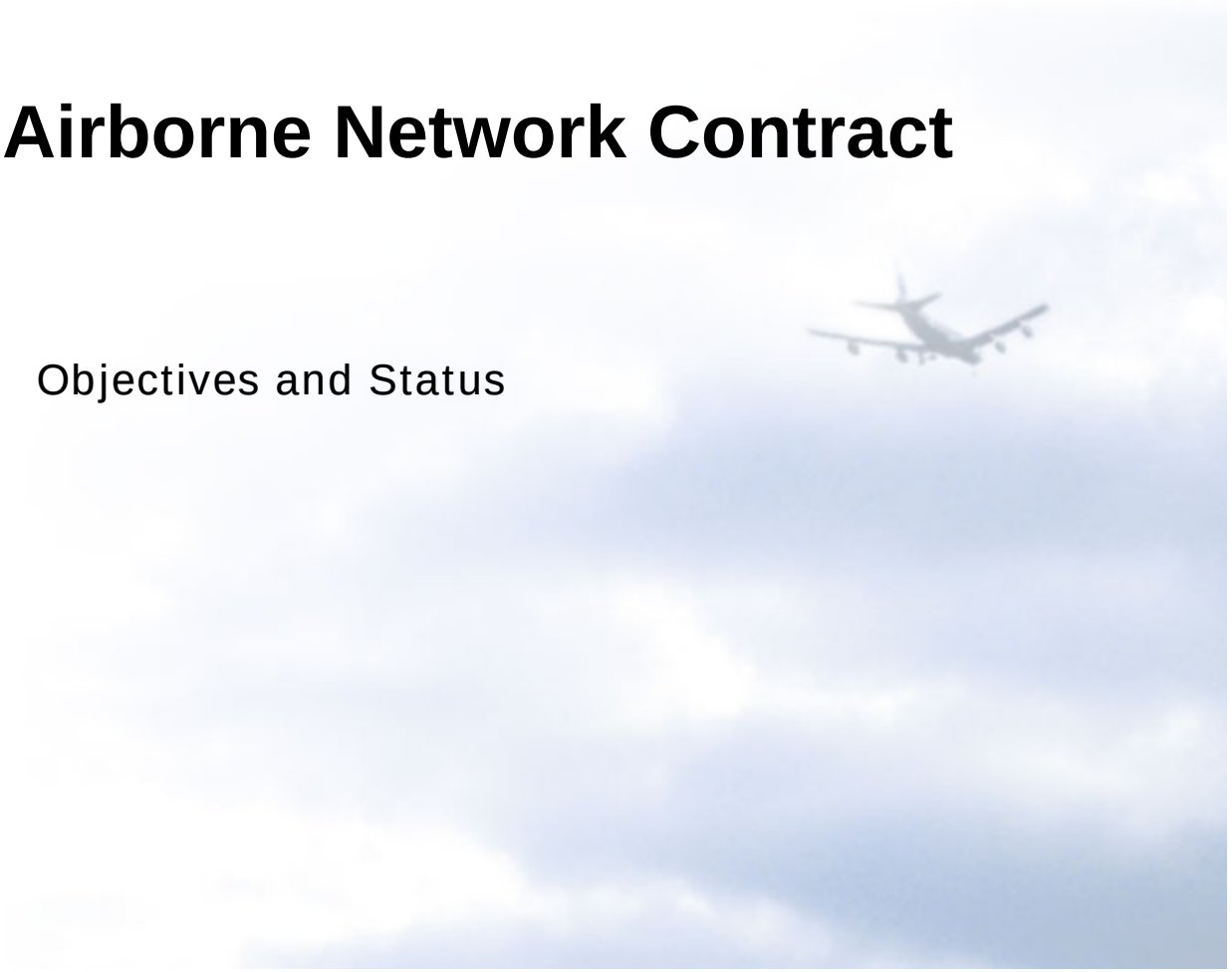
International Acceptance - International customers must be willing to buy

Network Connectivity provided to DoD just as commercial telephone, internet, and SATCOM service.

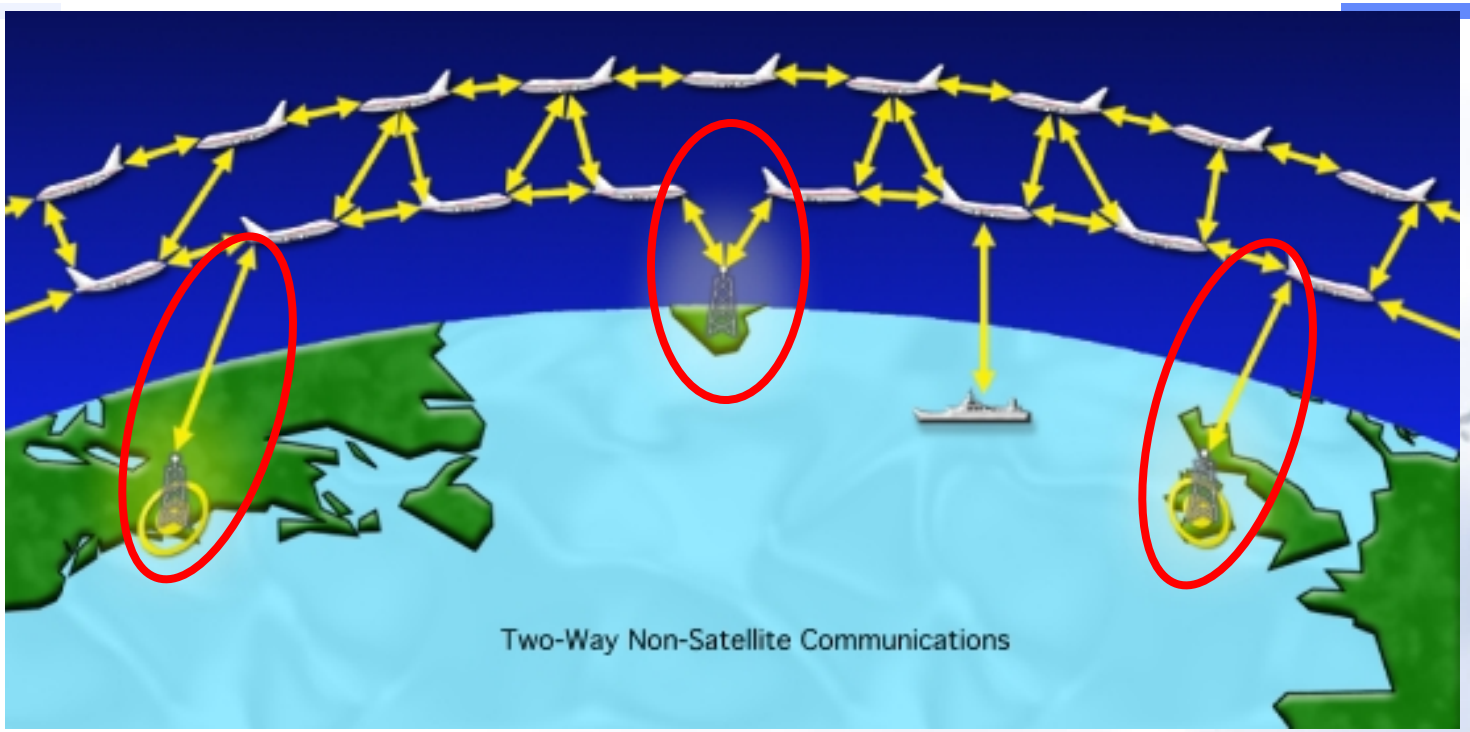


Broadband Airborne Network Contract

Objectives and Status



Focus on Air / Ground Link



Mesh Network tied to Terrestrial Networks via Air<->Ground Links
This is the Hard Part - Atmosphere, Weather, etc.

End to end testing

Flight Test with FAA

Goals

- Link Characterization - Rate and Range
- Feasibility of Directional/Directional Link to Moving Platform
- Demonstration of Network Applications

Equipment Installation

- Ku-band Directional Link - Global 5000 to Ground Station
- 900 MHz Omni Directional Link - Convair/Global/Ground

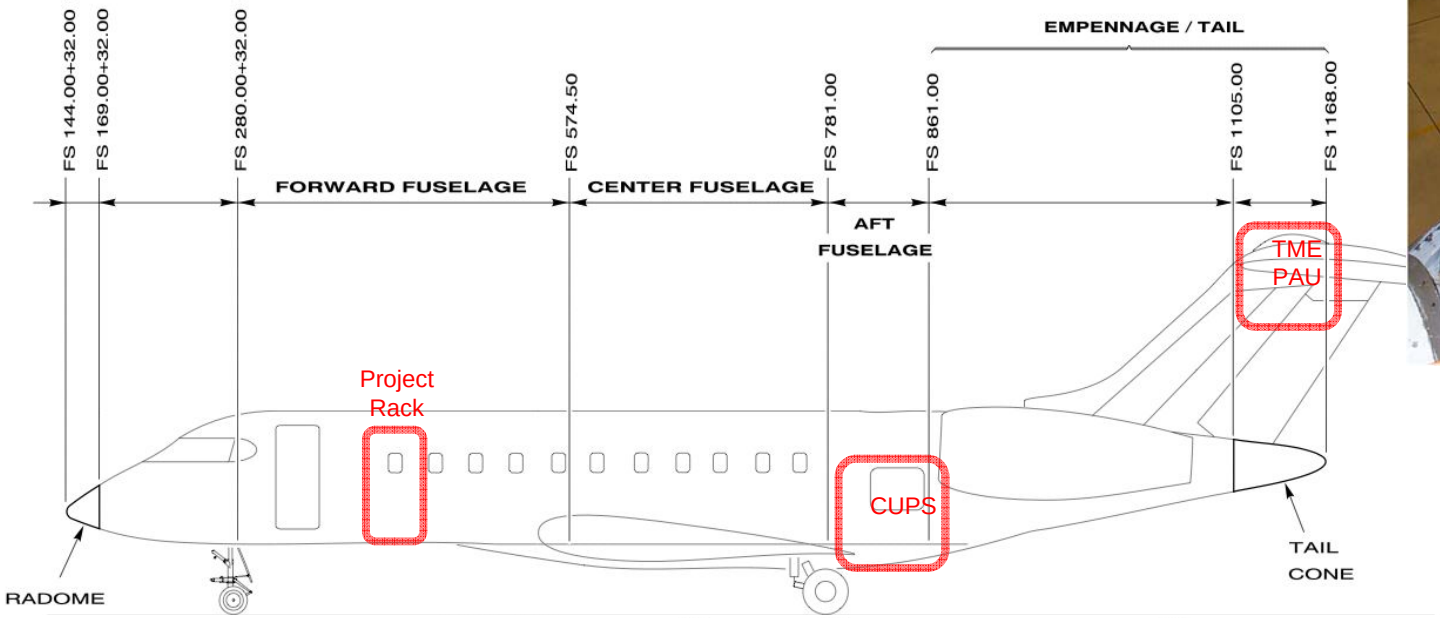
Leverage available off-the-shelf hardware

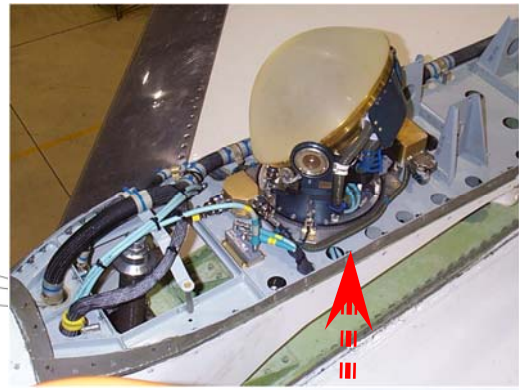
- AeroSat Ku-band Satcom Antenna
  - Limited look-down angle for STC'd Installation
- Commercial Air-Qualified Power Amp and Up/Downconverter
- Commercial Modems
  - Modulation Rotation every 30 seconds
    - QPSK OQPSK 8PSK 16QAM
    - 1,5,17.5,20,45Mbps

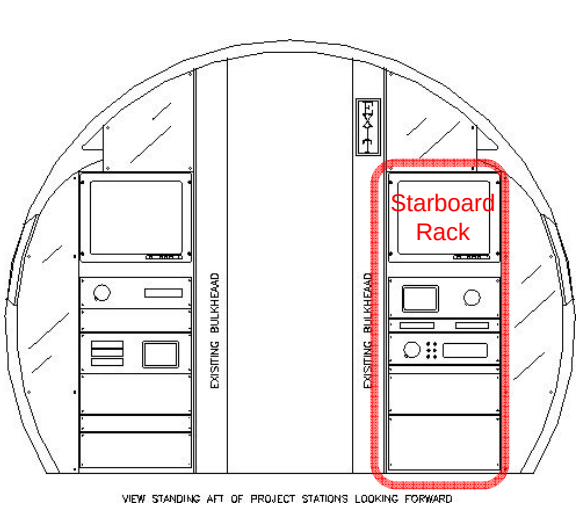
FAA Broadband Airborne Network Demonstration Goals and Objectives

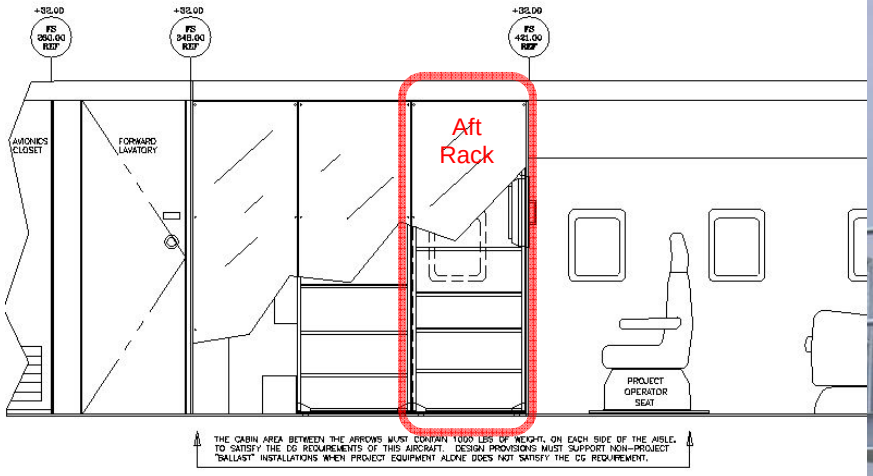
- Demonstrate a high speed full duplex data link from a ground station to an aircraft
  - Up to 45 Mbps out to 150 nautical miles
  - Up to 5 Mbps from 150 nautical miles to 200 miles
- Relay a portion of that data link to a second aircraft
  - Up to 1 Mbps out to 10 nautical miles
  - Up to 100 kbps from 10 nautical miles to 100 nautical miles
- Ground station located on roof of hangar at WJHTC Atlantic City, NJ
- Aircraft flying over the ocean, east/northeast of ground station
- Data link supports Internet Protocol

Broadband Airborne Network Equipment Installations









N47 Project Rack

Up / Down Converter

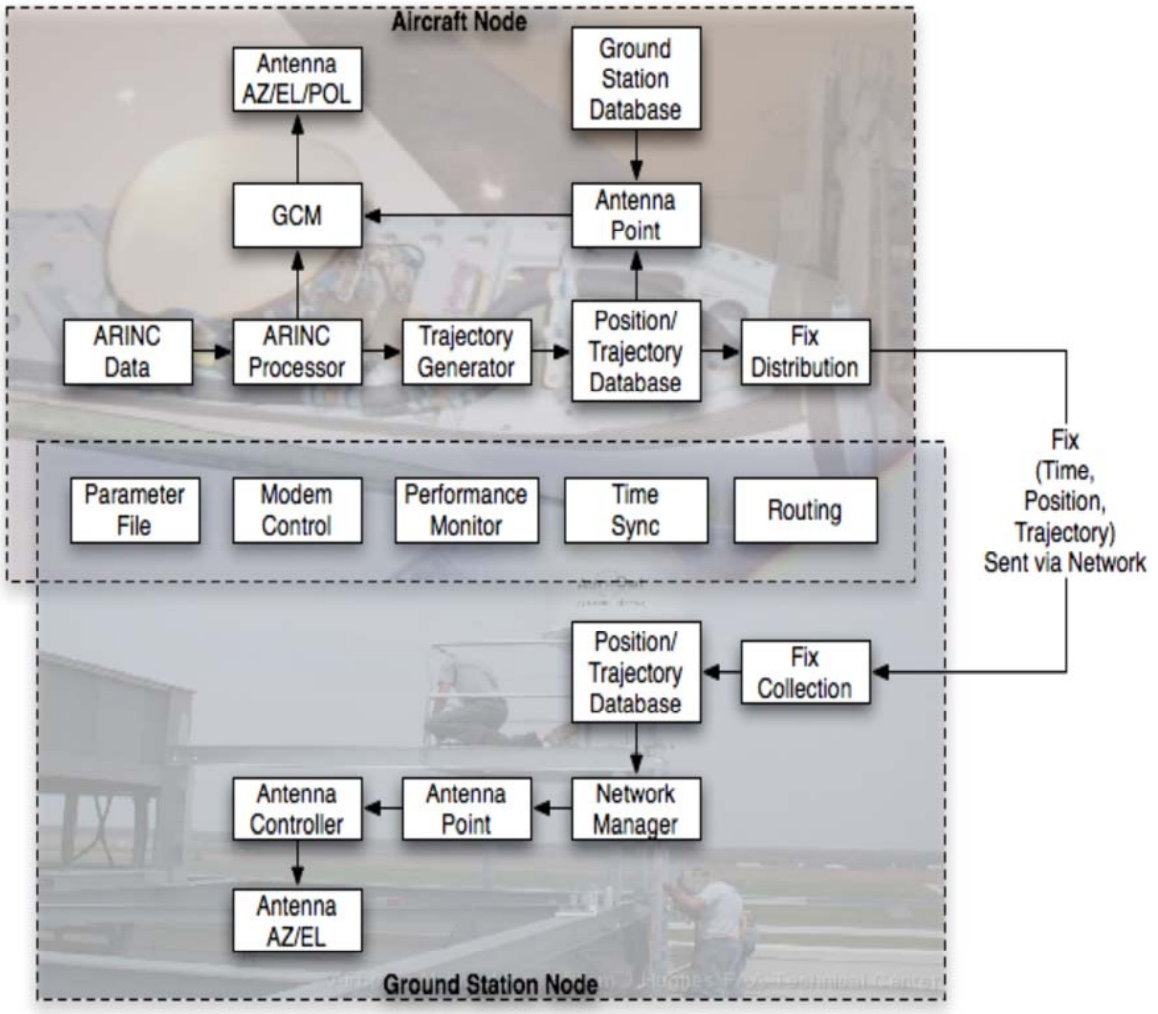
900-1500 MHz

11.2-11.45 GHz Tx
14.2 - 14.4 GHz Rx

Installed Functional Architecture

Directional <->Directional

- Track Aircraft & Ground
  - Nav Data from ARINC/GPS
  - Calc/Distribute 4D Trajectory
  - Omni to bootstrap
    - Air-to-Air
- Dual Modems
  - Primary Network Link
    - Applications
    - Position Updates
  - Link Characterization
    - Data Collection
    - Modulation Rotation
      - 5 to 45 kbps
- Aircraft
  - Multi-User Access via Ethernet Switch
- Ground Station
  - VPN Access to SWiM Lab

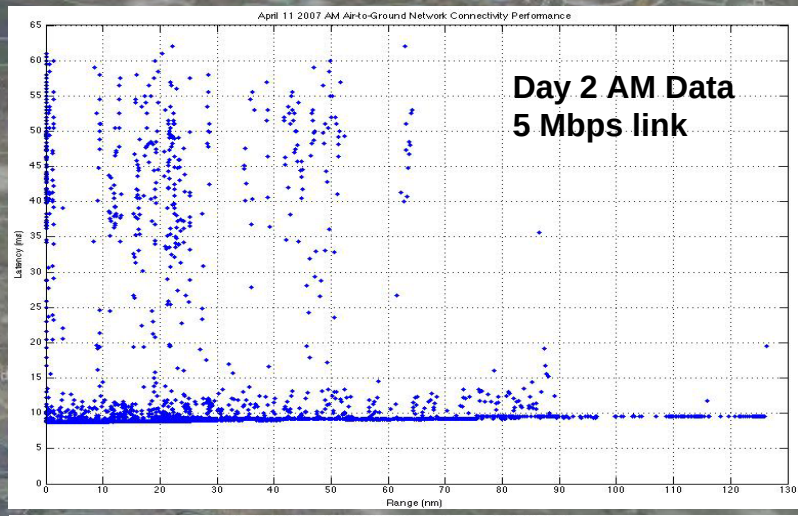


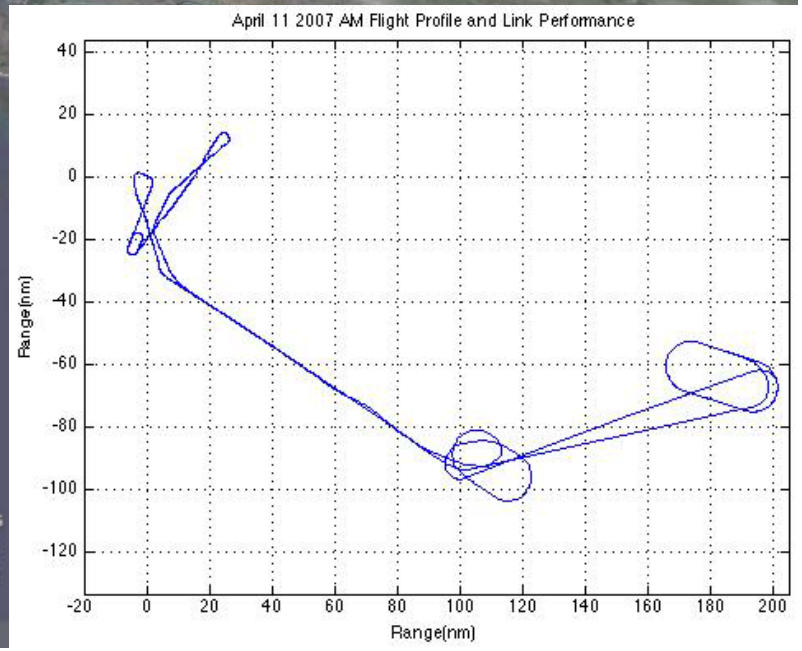
Demo Accomplishments

- First In-Flight Link to System-wide Information Management network (SWIM).
  - Encrypted Data Transfer Via VPN Link
  - Files Sizes of Approximately 1/4, 1, and 20 Mbytes,
    - Real-time Imagery, Aircraft Manuals, and a Video File.
- Real-time Situational Awareness Display
  - Range/bearing to Participating Aircraft and to the Ground Station.
    - Relative and True Bearings
  - Graphical Position Plot with Overlay of Real-Time NWS Weather Radar Loops
- Real-time Video Conferences
  - Typical Link Latency < 9 msec
  - Operator, Passenger, and Flight-Station video, 20fps
  - real-time feedback of link quality and latency on-par with wired networks.
- Link Characterization
  - Data Rates from 1 Mbps to 45 Mbps
- Air-to-Air-to-Ground data relay

Link Characterization

- Maximum range flown Day 2 PM was 170 nm.
  - 45 Mbps Link
    - 161 nm with a corrected BER of 5E-5.
    - Error Free link closure at 154 nm.
    - Maximum measured range was 161 nm
  - 25 Mbps link
    - 154 nm with a corrected BER of 5E-8.
    - Maximum measured range was 154 nm
  - 20 Mbps link
    - 154 nm with a corrected BER of <2E-10.
    - Maximum measured ranges was 154 nm
  - 17.5 Mbps link
    - 157 nm with a corrected BER of <1E-10.
    - Maximum measured ranges was 157 nm
  - 5 Mbps link
    - 167 nm with a corrected BER of <1E-10
    - Maximum measured ranges was 167 nm
  - 1 Mbps link
    - 170 nm with a corrected BER of <1E-15
    - Maximum measured ranges was 170 nm

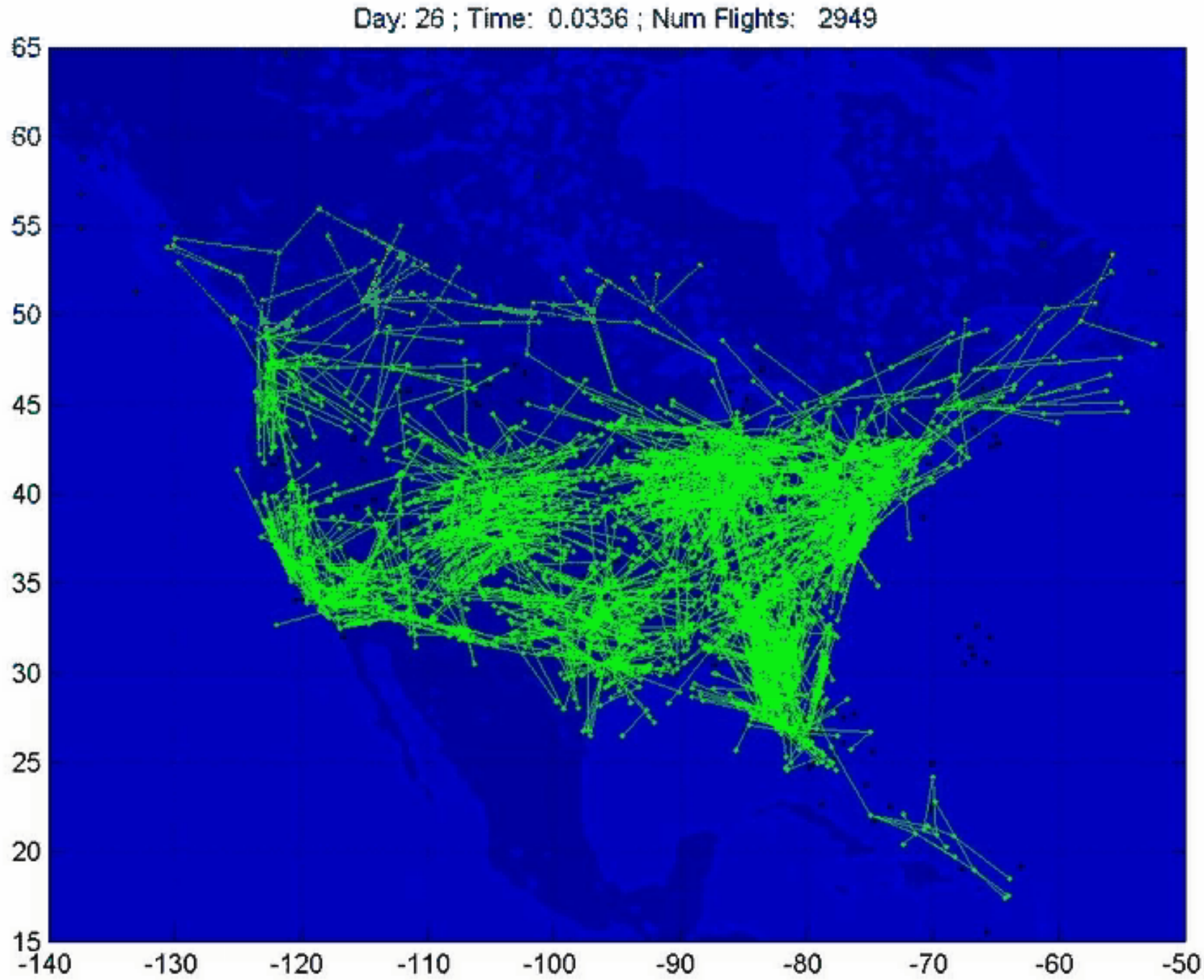




Air-to-Ground Videoconference

Flight Station Video Conferences

- Re-Compressed/Transcoded for presentation (avi)


Day: 26 ; Time: 0.0336 ; Num Flights: 2949
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-110
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-90
-80
-70
-60
-50

Next Steps

Full analysis of data

Incorporation of results into simulation

Frequency assessment